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THE COLLEGE OF AERONAUTICS
CRANFIELD

PRESSURE DROP IN "VELFLO" PIPE BENDS OF ONE DIAMETER THROAT RADIUS

by

C. S. CHAPMAN

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Tests carried out by the College of Aeronautics for Wilmot Breeden Ltd.

- by -

C. S. Chapman

SUMMARY

These tests were similar to those recorded in College of Aeronautics Note No. 95(2) by A. G. Smith, A.R.C.S., B.Sc., D.I.C., and J. P. H. Webber, to which the reader is referred.

This report gives experimental data for the pressure drop in "Velflo" pipe bends of 90° bend and one diameter throat radius. The bends were of 3" - 9" nominal diameter and the range was covered in steps of 1". Pressure drop data are provided in the form of pressure drop in the bends against nominal mean velocity for air of density 0.0763 lb/cu. ft. By "nominal mean velocity" is meant the mean velocity which would occur in a pipe of bore equal to the nominal for a given flow rate, and by "pressure drop" is meant the additional drop in pressure which occurs when a bend is inserted between two straight lengths. Both the bends and the pipes tested varied slightly in bore from the nominal diameter. Also given in the report is the non-dimensional form of the data, (useful in assessing consistency between the different tests) and the form of pressure drop against volume flow rate. This latter form is probably the most directly useful to customers of Wilmot Breeden Ltd.

CONTENTS

1. Apparatus

This is adequately shown in the diagram, Fig. 6, and the photograph of the test rig, Fig. 7, and needs no written explanation.

2. Reduction of Results

It can be easily shown that

$$\frac{\Delta P_p}{\frac{1}{2}\rho_p V_p^2} = \frac{\Delta P_p}{\Delta P_o} \left(\frac{D_p}{D_o}\right)^4 \frac{\rho_p}{\rho_o} \frac{1}{C_D^2} \qquad (1)$$

where

ΔP_p = Pressure drop between tappings on pipes at stations A and B (Fig. 6)

ρ_p = Density of air at mean pressure of A and B tappings

V_p = Velocity of air based on true volume flow and nominal pipe diameter

ΔP_o = Pressure drop across orifice

D_p = Nominal diameter of pipe

D_o = Diameter of orifice

ρ_o = Density of air upstream of orifice meter

C_D = Orifice coefficient defined by $M = \rho_o A_o V_o C_D$

where M = Mass flow of air in lb/second.

A_o = Area of orifice

V_o = Velocity of air, defined by $\Delta P_o = \frac{1}{2} \rho_o V_o^2$

The value of C_D was taken from the British Standards publication B.S. 1042 : 1943 - "Flow Measurement"

[C_D = "C" x "Z" x "E" where C = coefficient of discharge
Z = combined multiplier
E = "Velocity of approach" factor.]

$\frac{\Delta P_p}{\frac{1}{2}\rho_p V_p^2}$ must be a function of Reynolds number, defined by $R_p = \frac{\rho_p V_p D_p}{\mu_p}$

R_p was calculated by the numerical equation

$$R_p = 1.285 \times 10^6 \frac{M}{D_p \mu_p} \qquad (2)$$

where μ_p is the viscosity of the air relative to its value at 60°F, and D_p is the nominal pipe diameter in inches. Fig. 5 shows a graph of "relative viscosity" against temperature in $^\circ$C.

All the results taken are shown, reduced in the manner indicated above, in Fig. 1. In this and in the other figures $q = \frac{1}{2} \rho_p V_p^2$.

It will be seen that the points do not all lie on two lines. They should lie on two lines were all the test arrangements geometrically similar and the true pipe and bend diameters equal to the nominal. Most of the discrepancy is due to deviation from the latter condition. It is probable also that added friction loss was given by the elbow joints, particularly in the smaller diameter pipes.

Fig. 2 shows the results plotted in the form $\dfrac{\text{Pressure drop due to bend}}{\frac{1}{2} \rho_o V_o^2}$ against Rp. These might be called the "fundamental" results.

These results have been converted into two more readily usable forms. Firstly, as shown in Fig. 3, pressure drop has been plotted against velocity. By "velocity" is meant the mean velocity which the air would have if it were flowing in a pipe of diameter equal to the nominal diameter. Secondly, and probably the most directly useful form of results, Fig. 4 shows pressure drop against volume flow rate. Lines of velocity are also shown on this graph.

The final non-dimensional test results which were plotted in Fig. 1 are given in Tables 1 and 2. Fig. 8 shows the bend dimensions.

Accuracy of Results

The errors were:-

(a) Errors due to the static pressure taps A and B reading incorrectly. These taps were quadruplicated as a precaution and passed as satisfactory when the discrepancies were of the order of 1-2% of the dynamic head.

(b) Errors due to working near the lower limit of manometer sensitivity.

A satisfactory statement regarding the accuracy of the final results is difficulty to make but it is thought unlikely that there will be an error in excess of 10% in any curve of bend pressure drop. The pressure drops in the straight pipes agree to within 10-20% of the values given in "Friction Charts for Air Flow in Straight Ducts and Pipes" by R. H. Young and J. M. Gasiorck - Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E. C. 4. Publication 2007. Since the pipes tested had a different roughness from the pipes from which the latter were deduced this is a satisfactory agreement.

It is confidently thought that the results of Fig. 1 for the 5" - 9" diameter pipes and elbows would extrapolate satisfactorily for larger sizes of identical shape, but extrapolation to smaller sizes would require some care since smaller sizes would be less accurately similar.

The test results go down to a bend pressure loss of 0.05" of water. Extrapolation down to about 0.01" of water would be reasonable. It would be most difficulty and expensive to measure in this 0.01" of water range.

TABLE 1

Pressure Drops Along Straight Pipes

Final Experimental Results Given in Non-Dimensional Form. Ref. Fig. 1

3.0" Dia.		4.0" Dia.		5.0" Dia.		6.0" Dia.		7.0" Dia.		8.0" Dia.		9.0" Dia.	
Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$
.331	.28	.516	.257	.61	.20	.363	.256	1.127	.195	.913	.214	.94	.202
.561	.25	1.045	.202	1.31	.186	.817	.213	1.85	.188	1.92	.181	1.695	.200
.696	.24	1.495	.202	1.91	.185	1.13	.21	2.73	.176	2.91	.176	2.375	.194
.676	.221	1.95	.210	1.945	.169	1.445	.20	3.65	.171	3.76	.173	3.42	.184
1.23	.214	2.33	.207	2.57	.169	2.055	.196	4.40	.167	4.50	.165	4.68	.171
1.56	.209	2.32	.198	3.21	.160	3.015	.187	5.25	.167	4.64	.166	4.47	.159
2.045	.198	2.82	.195	3.79	.161	3.78	.174	5.94	.162	5.75	.157	5.68	.154
2.4	.193	3.4	.189	4.59	.158	4.47	.171	6.20	.158	6.59	.154	6.75	.152
2.84	.188	4.06	.186	5.20	.157	5.18	.169	7.12	.155	7.41	.150	7.75	.150
3.06	.191					5.82	.167	7.94	.156	8.12	.150	8.53	.148
						6.62	.167					8.98	.148

TABLE 2

Pressure Drops Along Pipes with 1D Radius Elbows

Final Experimental Results Given in Non-Dimensional Form. Ref. Fig. 1

3.0"Dia.		4.0"Dia.		5.0"Dia.		6.0"Dia.		7.0"Dia.		8.0"Dia.		9.0"Dia.	
Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$	Rp $\div 10^5$	$\Delta P/q$
.354	.558	.464	.522	.447	.4798	.3843	.4949	1.066	.441	1.072	.4048	1.0007	.427
.571	.555	.491	.517	.655	.4192	1.567	.396	1.836	.3957	2.15	.3797	1.668	.3991
.744	.517	.89	.487	1.327	.3766	1.585	.376	2.737	.375	3.224	.3615	2.303	.3294
.71	.510	1.12	.459	1.904	.374	2.419	.379	3.663	.347	4.31	.340	3.565	.3472
1.312	.4629	1.64	.491	1.931	.379	3.20	.3558	4.46	.3339	5.362	.335	4.716	.3307
1.613	.451	2.13	.429	2.51	.362	3.95	.343	5.22	.321	5.493	.3158	6.13	.3263
2.24	.4449	2.539	.411	3.25	.344	4.649	.340	5.997	.3117	6.556	.3109	7.182	.3327
2.614	.432	3.25	.3965	3.846	.3349	5.438	.3336	6.1914	.306	7.268	.3193	8.166	.3254
2.89	.436	3.757	.3962	4.5889	.327	6.05	.329	7.192	.313	8.218	.313	8.81	.3251
3.297	.436	4.287	.3928	5.196	.325	6.775	.327	7.916	.306	9.012	.316	9.14	.3195

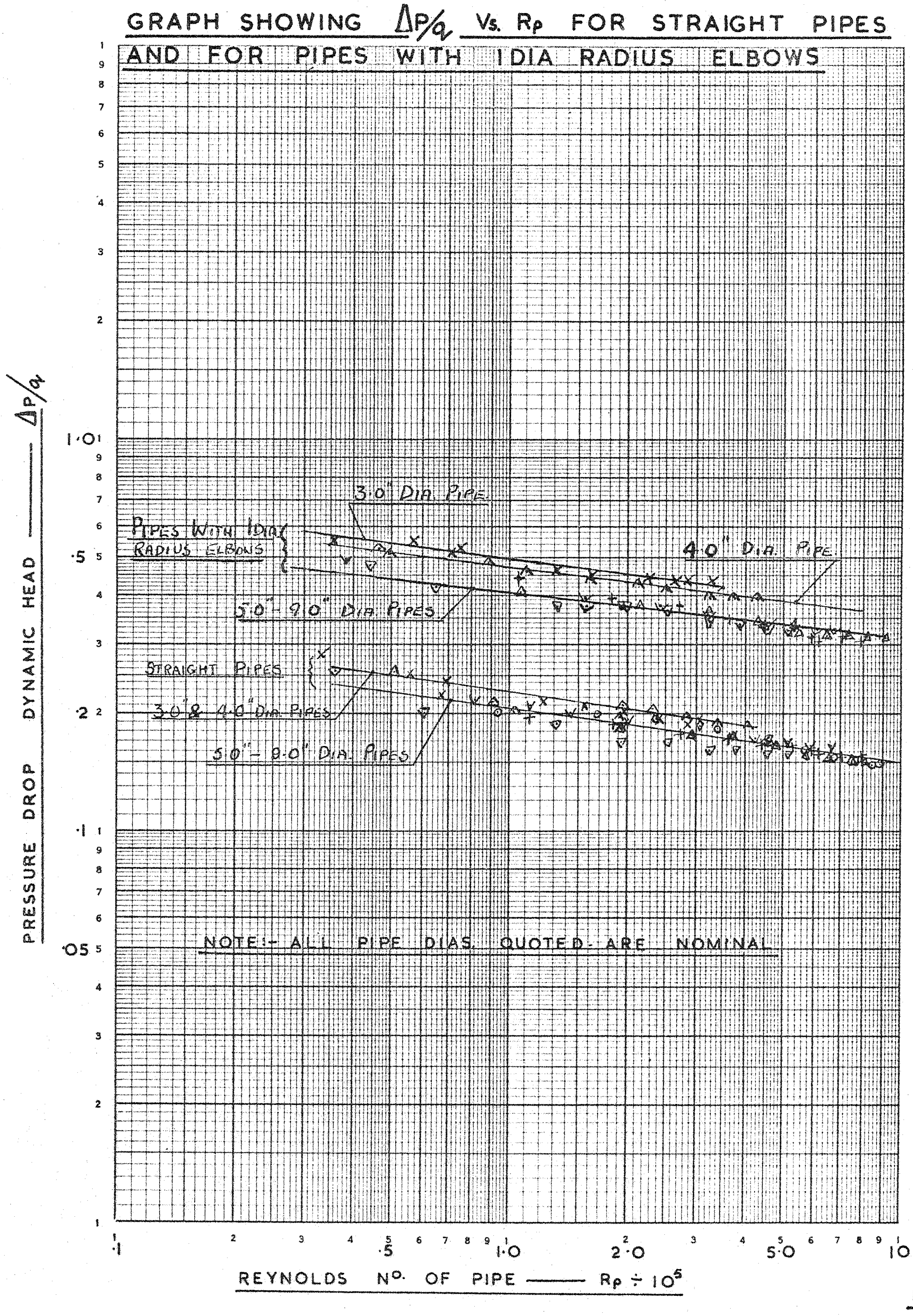

GRAPH SHOWING ΔP/q Vs. Rp FOR STRAIGHT PIPES AND FOR PIPES WITH 1 DIA RADIUS ELBOWS
PRESSURE DROP DYNAMIC HEAD —— ΔP/q
REYNOLDS No. OF PIPE —— Rp ÷ 10^5
PIPES WITH 1 DIA RADIUS ELBOWS
3.0" DIA. PIPE
4.0" DIA. PIPE
5.0" – 9.0" DIA. PIPES
STRAIGHT PIPES
3.0" & 4.0" DIA. PIPES
5.0" – 9.0" DIA. PIPES
NOTE:- ALL PIPE DIAS. QUOTED ARE NOMINAL

FIG. 1

GRAPH SHOWING $\Delta P/q$ Vs. Rp FOR 1 DIA. RADIUS ELBOWS ALONE

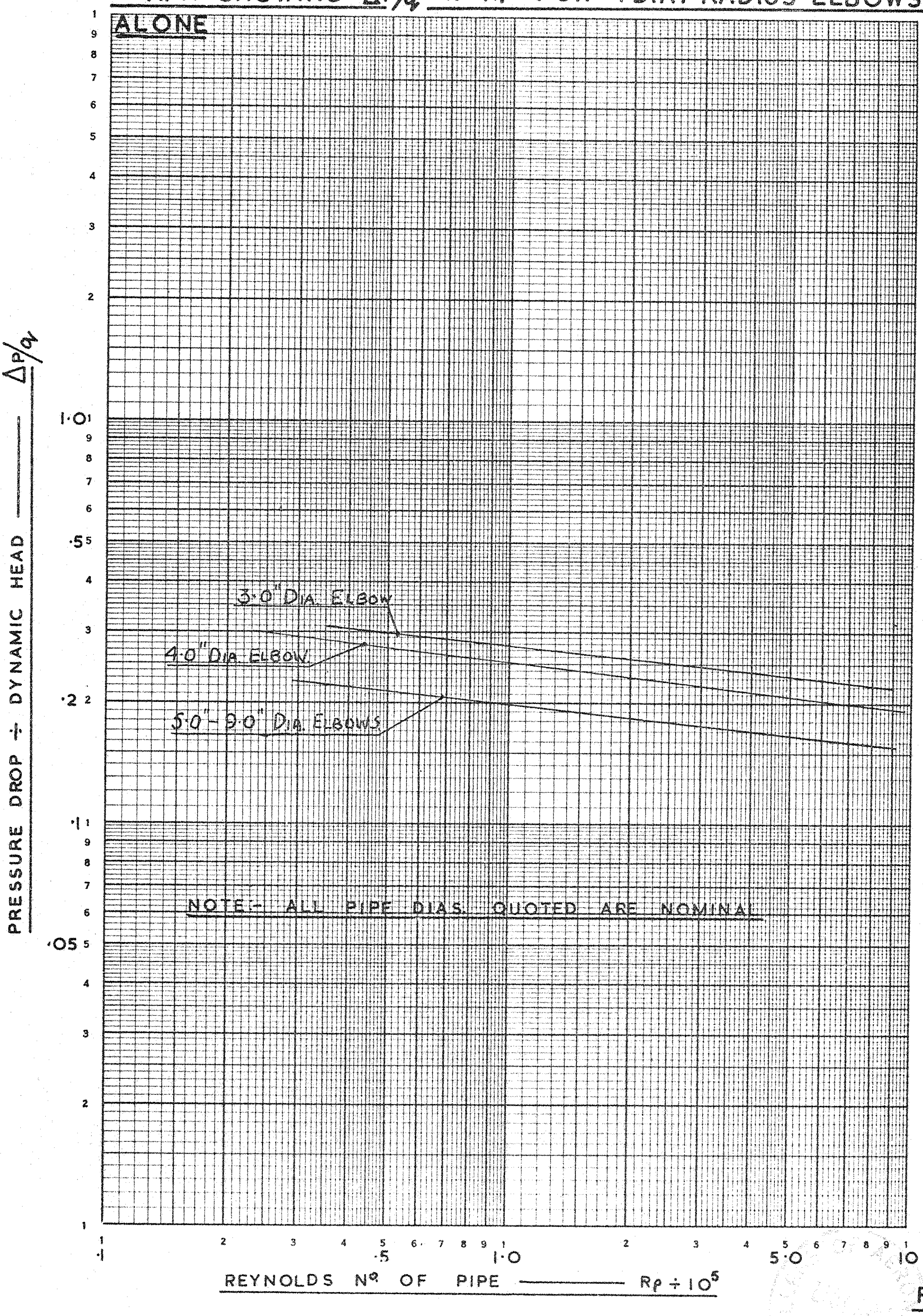


FIG. 2

GRAPH SHOWING PRESSURE DROP DUE TO 1DIA. RADIUS ELBOW Vs NOMINAL MEAN VELOCITY AT 0·0763 Lb/FT^3 DENSITY

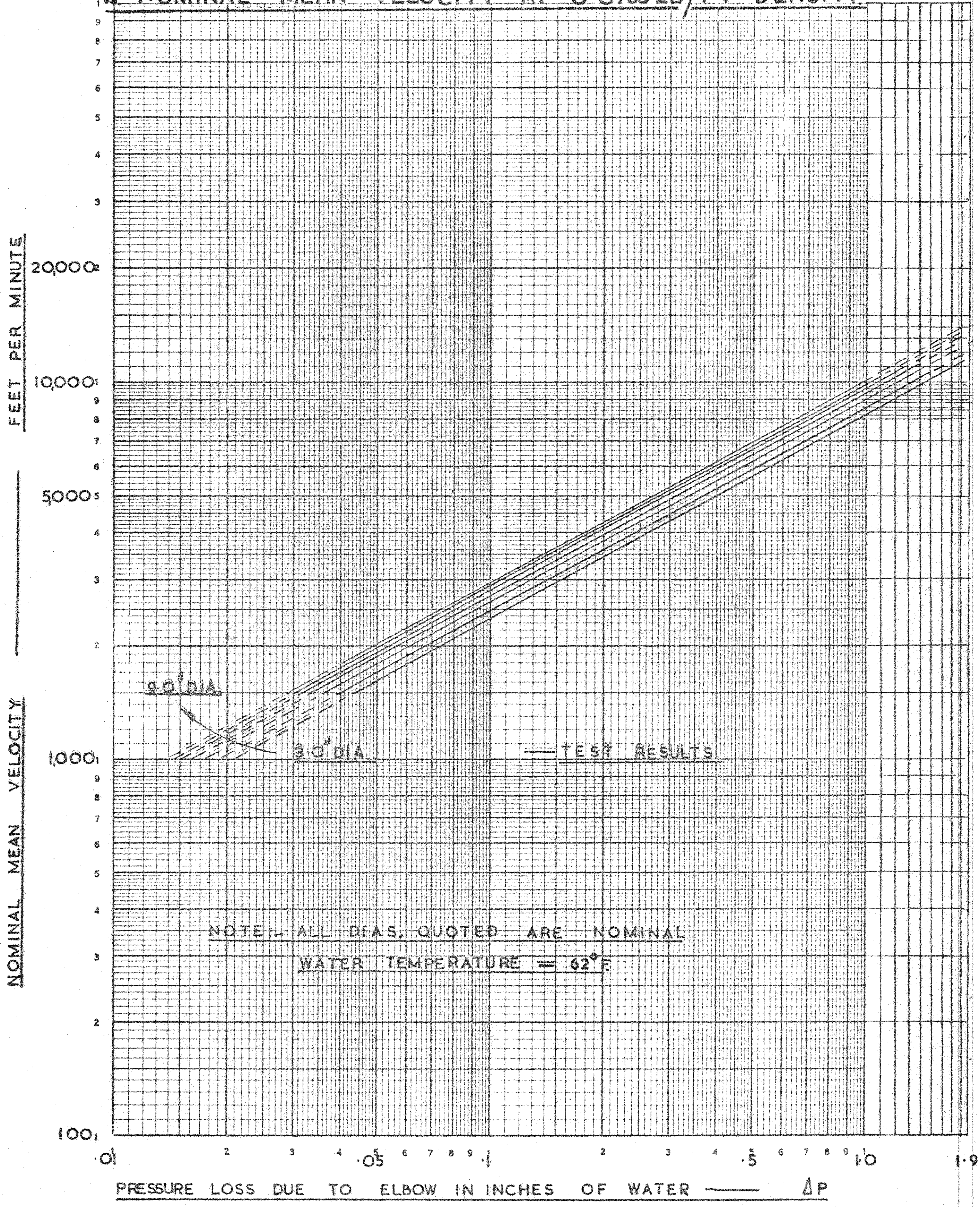


FIG.3

GRAPH SHOWING PRESSURE DROP DUE TO ELBOW Vs. VOLUME FLOW – I DIA. THROAT RADIUS ELBOWS

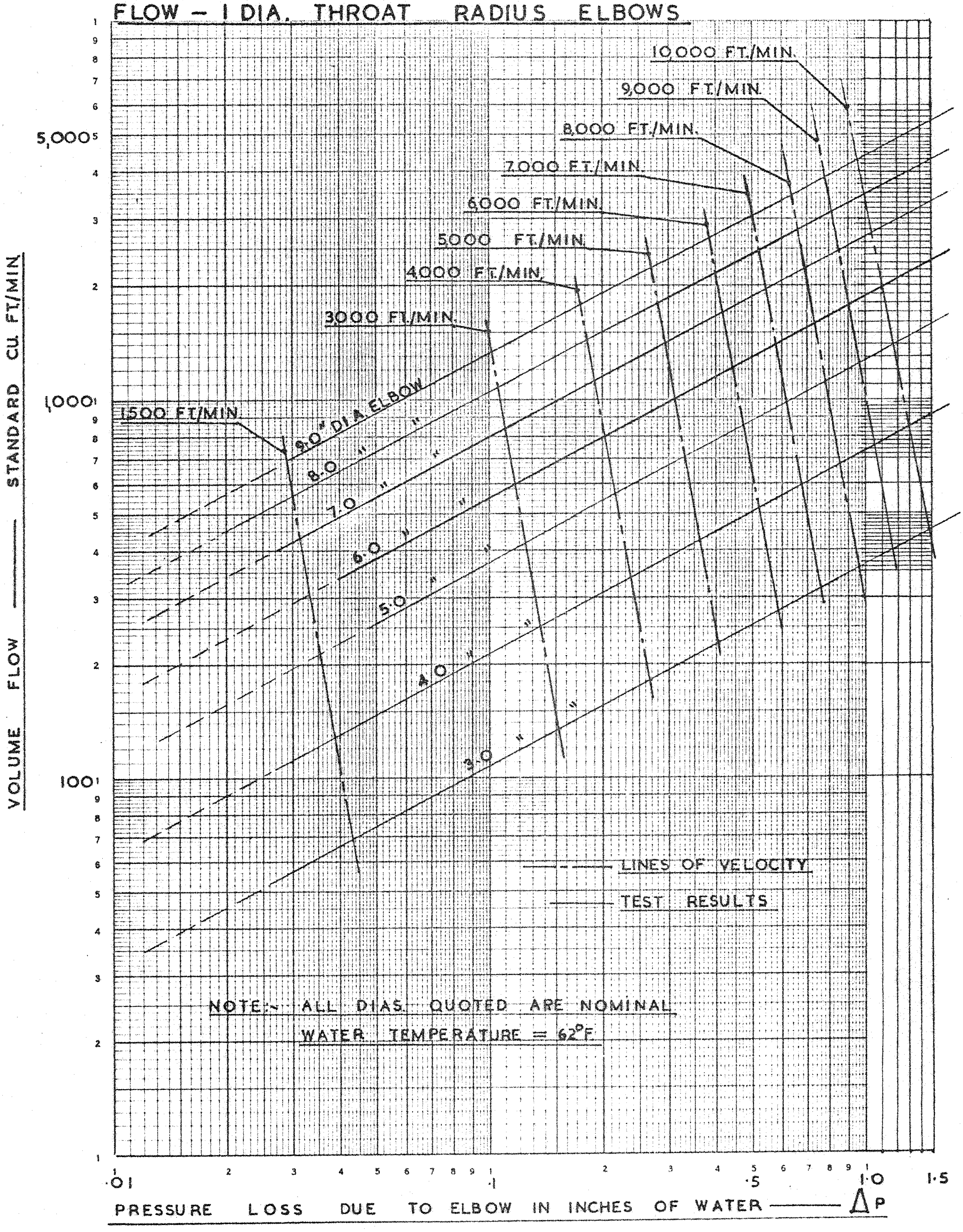


FIG. 4

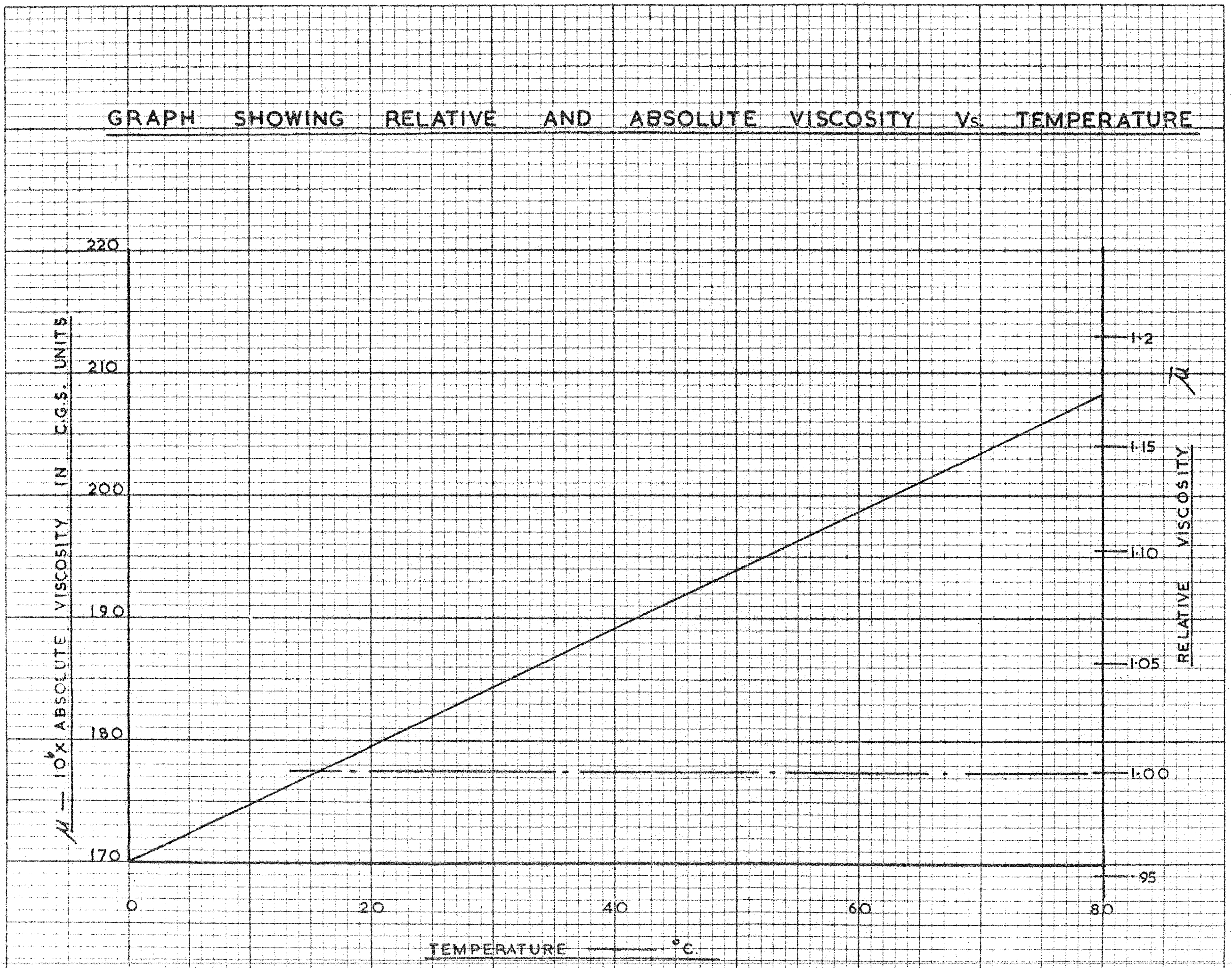

GRAPH SHOWING RELATIVE AND ABSOLUTE VISCOSITY Vs. TEMPERATURE
220
210
200
190
180
170
μ — 10⁶ x ABSOLUTE VISCOSITY IN C.G.S. UNITS
1·2
1·15
1·10
1·05
1·00
·95
RELATIVE VISCOSITY
0
20
40
60
80
TEMPERATURE — °C.

FIG. 5

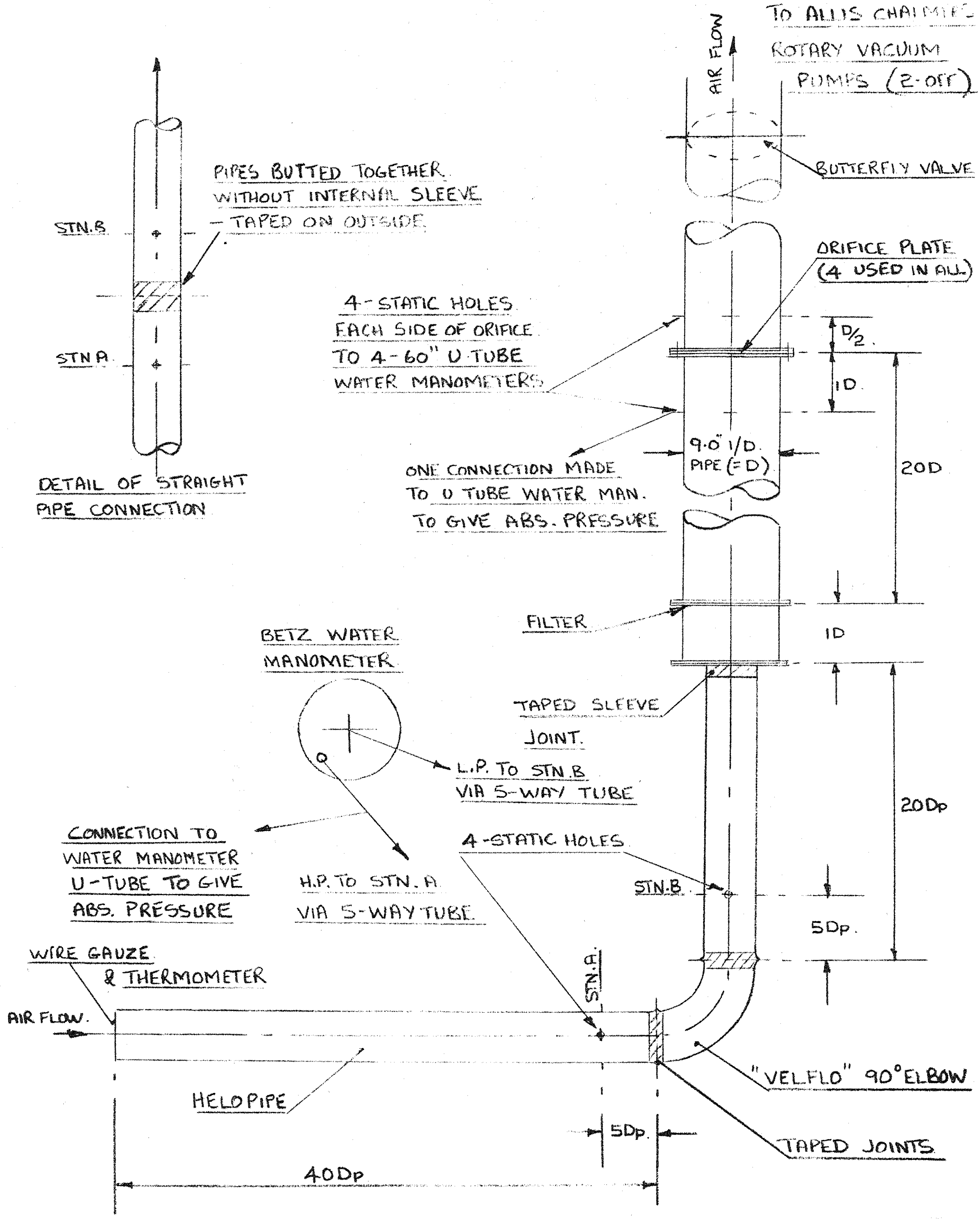
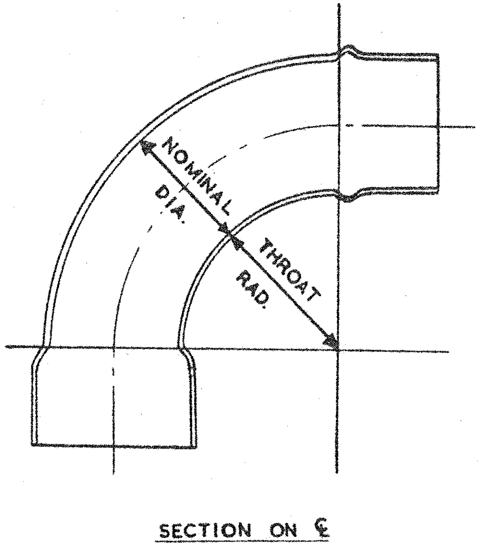


DIAGRAM OF TEST RIG PLAN VIEW

FIG 6



BEND DIMENSIONS

FIG. 8

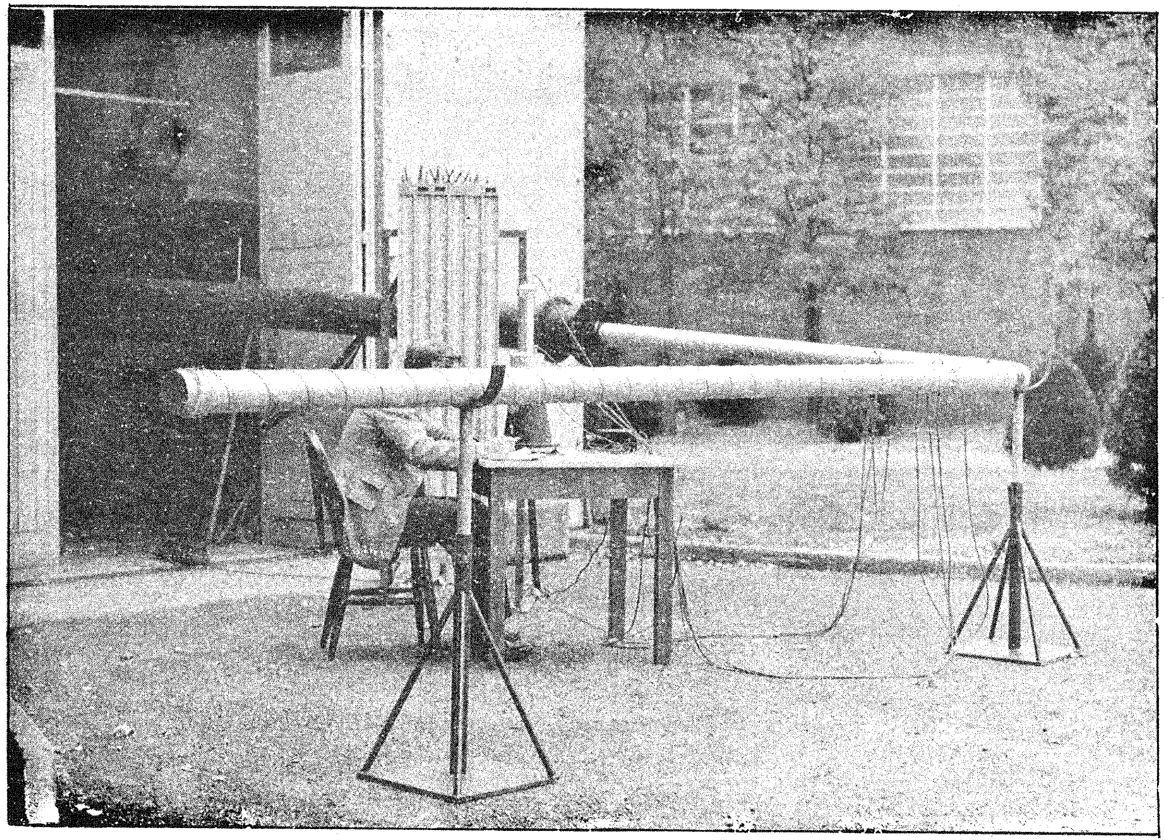


FIG. 7.